# SECTION 4
# Summary of Sediment Monitoring Data

This section presents sediment chemistry results for both offshore and beach stations sampled between 2005 and 2007. Benthic infauna results for the West Point TP outfall samples analyzed in 2006 are also presented.

Sediment samples were collected from 8 beach stations in 2005, 19 offshore stations around the West Point Treatment Plant outfall in 2006, and 14 ambient offshore stations in 2007. The 2005 sediment data are presented in Appendix B. Station locator maps are provided in Section 2, along with specific station information such as matrix, parameters, and frequency measured. A summary of results for specific parameters (e.g., metals, organics) are provided in this section.

## 4.1 2005 Beach Sediments

Beach (intertidal) sediment samples were collected in August 2005 from four ambient and four outfall stations located at Richmond Beach, Golden Gardens, Normandy Park, Salt Water State Park, Carkeek Park, West Point, Alki Point, and Vashon Island. Beach sediment sampling stations are shown in Section 2. Samples were analyzed for grain size distribution, oil and grease, total organic carbon, metals, and trace organic parameters, including chlorinated pesticides, polychlorinated biphenyls (PCBs), and semivolatile organic compounds.

### 4.1.1 Conventionals

Grain size distribution results show that sediments collected from all eight stations were comprised mainly of sand and gravel. Percent fine material in all eight samples was very low, ranging from 1.5 to 4.3%.

Oil and grease was detected at all eight stations with concentrations ranging from 180 to 250 milligrams per kilogram, normalized to dry weight (mg/Kg DW).

Organic carbon was not detected in the samples collected from Richmond Beach (JSVW04), Carkeek Park (KSHZ03), and West Point (KSSN05). Total organic carbon concentrations in samples collected from the other five intertidal stations ranged from 670 to 4,140 mg/Kg DW or 0.07 to 0.41%. These organic carbon concentrations are considered low for Puget Sound and would be expected in coarse sediments such as these.

### 4.1.2 Metals

Samples were analyzed for 14 metals (see Appendix B). Four metals – arsenic, cadmium, selenium, and silver – were not detected in any of the samples. Mercury was detected in two of the eight samples, collected from Golden Gardens (KSLU03) and Alki Beach (LSKS01). The remaining nine metals were detected in all five samples. Table 4-1 shows the concentration

ranges for the detected metals. There was very little variation in metal concentrations between intertidal stations.

Table 4-1 also shows the Washington State Sediment Management Standards (SMS) sediment quality standard (SQS) chemical criteria for the eight metals regulated under the SMS program (Ecology, 1995). Detected concentrations of chromium, copper, lead, mercury, and zinc in the eight intertidal samples collected in 2005 were all well below their respective SQS chemical criteria.

**Table 4-1.** Metal Concentrations in 2005 Intertidal Sediment Samples

| Metal | Detection Frequency | Concentration Range (mg/Kg DW) | SQS (mg/Kg DW) |
|---|---|---|---|
| Aluminum | 8/8 | 5,360 - 9,170 | -- |
| Arsenic | 0/8 | -- | 57 |
| Beryllium | 8/8 | 0.068 - 0.12 | -- |
| Cadmium | 0/8 | -- | 5.1 |
| Chromium | 8/8 | 12.5 - 24.1 | 260 |
| Copper | 8/8 | 5.13 - 10.4 | 390 |
| Iron | 8/8 | 8,100 - 13,300 | -- |
| Lead | 8/8 | 2.2 - 7.9 | 450 |
| Manganese | 8/8 | 109 - 204 | -- |
| Mercury | 2/8 | <MDL (0.024) - 0.027 | 0.41 |
| Nickel | 8/8 | 12.8 - 31.7 | -- |
| Selenium | 0/8 | -- | -- |
| Silver | 0/8 | -- | 6.1 |
| Zinc | 8/8 | 22.2 - 30.9 | 410 |

mg/Kg DW – Milligrams per kilogram on a dry weight basis.

### 4.1.3 Organics

Samples were analyzed for 20 chlorinated pesticides and seven PCB Aroclors® (see Table B-3, Appendix B). Chlorinated pesticides and PCBs were not detected in any of the eight samples.

The samples were also analyzed for 72 semivolatile organic compounds including polynuclear aromatic hydrocarbons (PAHs), chlorobenzenes, phthalates, and phenols (see Table B-4, Appendix B). A total of 19 semivolatile organic compounds were detected in one or more of the intertidal sediment samples. The detected compounds included benzoic acid, benzyl butyl phthalate, di-n-octyl phthalate, hexachlorobenzene, phenol, pyridine, and 11 PAHs (anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene).

Two other phthalate compounds were also detected – bis(2-ethylhexyl) phthalate and di-n-butyl phthalate. These plasticizers are ubiquitous in the environment, however, they are also common

laboratory contaminants. Quality control data indicated that positive analytical results for these two phthalates were most likely the result of laboratory contamination during sample analysis. Results for both of these phthalates should be considered estimated.

Table 4-2 shows the detection frequency and concentration ranges for the detected semivolatile organic compounds. This table also provides the dry-weight normalized SQS criteria for benzoic acid and phenol and the dry-weight normalized Lowest Apparent Effects Threshold (LAET) values for 16 of the other compounds (EPA, 1988). These 16 compounds all have corresponding SQS chemical criteria, which are based on organic-carbon normalized values. When assessing sediment quality, however, it is more appropriate to compare sample data to dry-weight normalized LAET values when the organic carbon content of the samples is less than 0.5% (Ecology, 1992). There are no Washington State sediment quality guidelines for pyridine.

**Table 4-2.** Organic Concentrations in 2005 Beach Sediment Samples

| Trace Organic Compound | Detection Frequency | Concentration Range (µg/Kg DW) | SQS/LAET (µg/Kg DW) |
|---|---|---|---|
| Anthracene | 1/8 | <MDL (4.8) - 31.3 | 960 |
| Benzo(a)anthracene | 6/8 | <MDL (2.4) - 78.1 | 1,300 |
| Benzo(a)pyrene | 5/8 | <MDL (3.6) - 93.4 | 1,600 |
| Benzo(b)fluoranthene | 5/8 | <MDL (3.6) - 74.4 | 1,600 |
| Benzo(k)fluoranthene | 5/8 | <MDL (3.6) - 75.7 | 1,600 |
| Benzo(g,h,i)perylene | 2/8 | <MDL (9.6) - 46.8 | 670 |
| Chrysene | 5/8 | <MDL (4.8) - 104 | 1,400 |
| Fluoranthene | 5/8 | <MDL (9.6) - 275 | 1,700 |
| Indeno(1,2,3-c,d)pyrene | 1/8 | <MDL (11) - 41.1 | 600 |
| Phenanthrene | 4/8 | <MDL (4.8) - 70.1 | 1,500 |
| Pyrene | 6/8 | <MDL (4.8) - 207 | 2,600 |
| Benzoic Acid | 8/8 | 78 - 257 | 650 |
| Benzyl Butyl Phthalate | 3/8 | <MDL (7.2) - 36.3 | 63 |
| Di-n-octyl Phthalate | 1/8 | <MDL (9.6) - 31.0 | 6,200 |
| Hexachlorobenzene | 1/8 | <MDL (0.79) - 50.5 | 22 |
| Phenol | 4/8 | <MDL (11) - 25.8 | 420 |
| Pyridine | 1/8 | <MDL (32) - 38 | -- |
| Bis(2-ethylhexyl) Phthalate** | 8/8** | 19.1 - 160** | 1,300 |
| Di-n-butyl Phthalate** | 7/8** | <MDL (6.7) - 43.0** | 1,400 |

µg/Kg DW – Micrograms per kilogram on a dry weight basis.
**Data are considered highly suspect due to likely laboratory contamination during sample analysis.

A more detailed summary of detected compounds is provided below.

Benzoic acid was detected at all eight intertidal stations at concentrations ranging from 78 to 257 µg/Kg DW. This compound can be introduced into the environment from anthropogenic sources (food preservation, dyes, cigarettes), however, it is also a naturally-occurring byproduct of the

metabolic processes in shellfish and other benthic infauna. The highest detected benzoic acid concentration of 257 µg/Kg DW is well below the SQS chemical criterion of 650 µg/Kg DW.

Benzyl butyl phthalate was detected at the West Point (KSSN05), Normandy Park (MTLD03), and Salt Water State Park (NTAK01) stations at concentrations of 27.8, 36.3, and 23.7 µg/Kg DW, respectively. These concentrations are all well below the LAET value of 63 µg/Kg DW. Benzyl butyl phthalate is a common plasticizer found in many household, commercial, and industrial products.

Di-n-octyl phthalate was only detected at the Salt Water State Park station, at a concentration of 31.0 µg/Kg DW, which is well below the associated LAET value of 6,200 µg/Kg DW. Di-n-butyl phthalate is another common plasticizer.

Hexachlorobenzene was only detected at the Normandy Park station, at a concentration of 50.5 µg/Kg DW. This concentration is greater than the LAET of 22 µg/Kg DW. There is no known potential source for hexachlorobenzene contamination at Normandy Park, however, this compound is still in use as an active ingredient in some pesticides and has been a component of some wood preservatives in the past.

Phenol was detected at two of the ambient stations – Golden Gardens (KSLU03) and Normandy Park – and two of the outfall stations – Alki Beach (LSKS01) and Vashon Island (MSJL01) – at concentrations ranging from 12 to 25.8 µg/Kg DW, all well below the SQS chemical criterion of 420 µg/Kg DW. This compound is a component of many disinfectants, both household and industrial.

Pyridine was only detected at the Richmond Beach station (JSVW04), at a concentration of 38 µg/Kg DW, which is just slightly above the range of method detection limits for this compound (32 to 36 µg/Kg DW). Potential sources of pyridine may include antifreeze and some fungicides.

As discussed, detected concentrations of bis(2-ethylhexyl) phthalate and di-n-butyl phthalate should be considered as estimated and most likely the result of laboratory contamination during sample analysis. The detected phthalate concentrations, while highly suspect, are also all well below their respective LAET values.

One or more PAH compounds were detected in samples collected from three of the four outfall stations and three of the four ambient stations. PAH compounds were not detected at the Richmond Beach or Vashon Island stations. Total PAH concentrations at five of the six remaining stations were very low – ranging from 8.4 to 140 µg/Kg DW. The total PAH concentration of 1,100 µg/Kg DW detected at the Salt Water State Park station was significantly higher than the other five stations at which PAHs were detected. A potential source for elevated PAHs at this station might be stormwater runoff from the large asphalt parking lot in the park, introduced to intertidal sediment either directly or via the stream that runs through the park and empties into Puget Sound. Although elevated, the total PAH concentration at the Salt Water State Park station is still well below the LAET of 9,100 µg/Kg DW.

# 4.2 2006 West Point TP Outfall Offshore Sediments

The primary goal of the 2006 West Point outfall sediment monitoring event was to meet the sediment monitoring requirement of the County's West Point TP NPDES permit. Secondary goals were to reassess and fully characterize sediment quality at two existing monitoring stations that previously appeared to exceed SMS chemical and/or biological criteria.

Sampling for the 2006 West Point sediment monitoring event was designed to allow a full characterization of sediment quality in the immediate vicinity of the outfall as well as allowing assessment of sediment thought to be outside the direct influence of the outfall. To aid sample station placement, King County deployed four Acoustic Doppler Current Profilers (ADCPs) for five weeks beginning in February 2003 at specific locations around the outfall to better understand oceanographic currents that may affect the effluent plume and sediment deposition. As expected, the current meter study indicated a net northerly flow in the vicinity of the West Point outfall (King County, 2005). As a result of the current meter study and previous data, a total of 19 stations were sampled in October 2006, both proximal (16 stations) and distal (3 stations) to the outfall. The proximal stations were placed in three north-to-south transects (Figure 4-1).

All 19 samples were analyzed for sediment conventionals, metals, and organic compounds and 11 samples (3 replicates per sample) were analyzed for benthic infaunal community abundance and structure. Ten of the benthic community samples were proximal to the outfall and one was distal.

## 4.2.1 Conventionals

Sediment conventional analyses included grain size distribution, TOC, ammonia nitrogen, and total sulfides. Table 4-3 summarizes analytical results for sediment conventionals.

The grain size analysis shows that sediments in the vicinity of the West Point outfall are coarse-grained, comprised mainly of sand, with a low percentage of fine material (silt and clay). Percent fines ranged from 1.3 to 11.2%. This distribution of particle size is indicative of a high-energy, low-depositional environment.

TOC results ranged from 0.10 to 0.41%, which is considered low for Puget. These low TOC results are expected, given the composition of substrate in the vicinity of the West Point outfall. The 2006 results are similar to past monitoring years (King County 1998, 2000, 2001).

Ammonia was detected in all 19 samples at concentrations ranging from 0.367 to 3.33 mg/Kg DW. Total sulfides were detected in 6 of 19 samples. The dry weight-normalized MDL for total sulfides ranged from 0.63 to 0.70 mg/Kg DW. Detected total sulfide results ranged from 0.69 to 5.87 mg/Kg DW. There is no apparent concentration gradient for either ammonia or total sulfides, with respect to the West Point outfall.

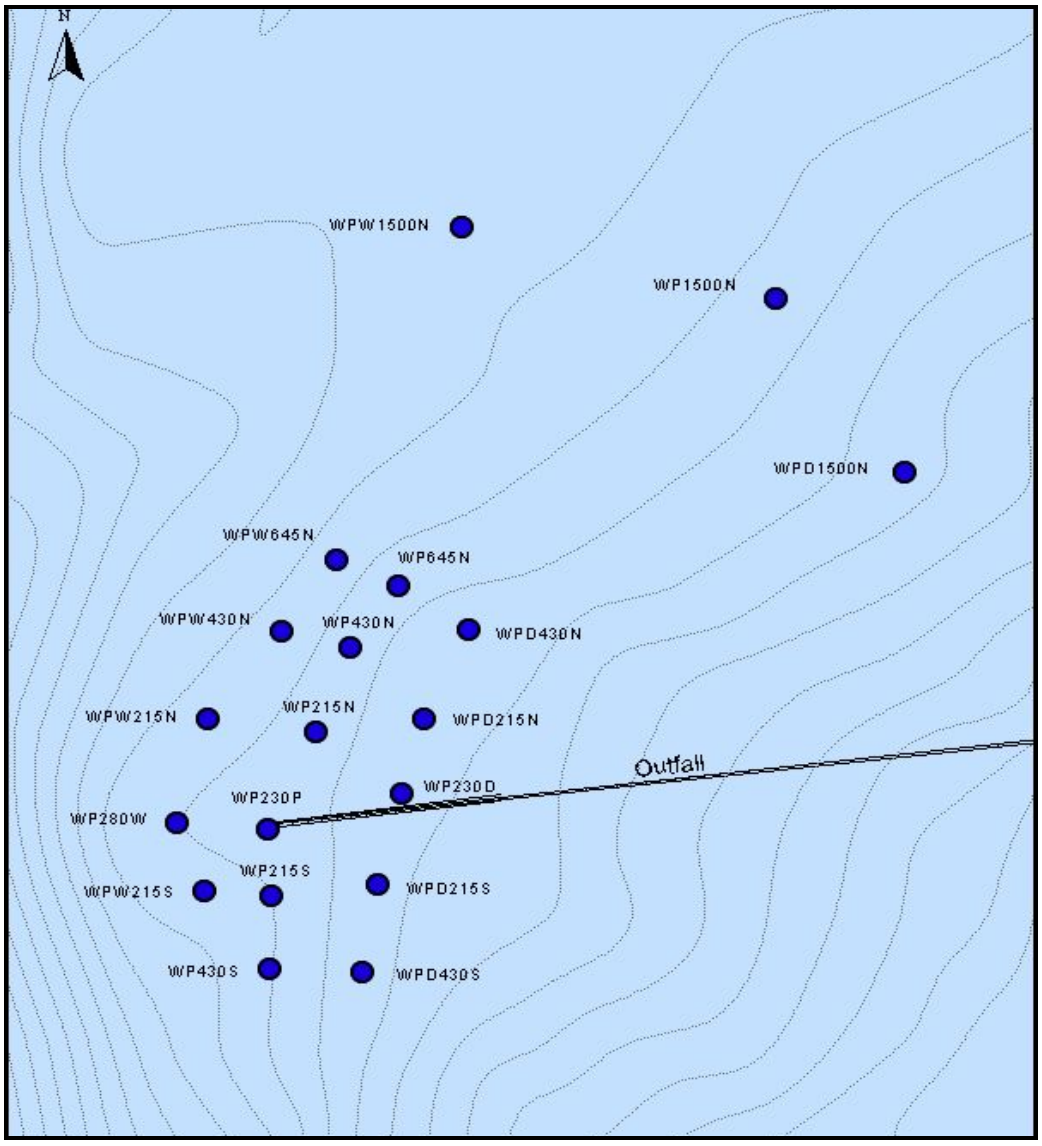


**Figure 4-1.** West Point 2006 Sediment Stations

## 4.2.2 Metals

Metals results are presented in units of mg/Kg DW. Three of the eight metals regulated under SMS – chromium, copper, and zinc – were detected in all 19 samples; all at similar concentrations and all well below their respective SQS chemical criteria.

- Chromium – concentrations from 11.7 to 25.7 mg/Kg DW – SQS = 260 mg/Kg DW.
- Copper – concentrations from 5.08 to 13.6 mg/Kg DW – SQS = 390 mg/Kg DW.
- Zinc – concentrations from 19.9 to 40.7 mg/Kg DW – SQS = 410 mg/Kg DW.

**Table 4-3.** Summary of Sediment Conventional Results

| Station | % Fines | % TOC | Ammonia (mg/Kg DW) | Total Sulfides (mg/Kg DW) |
|---|---|---|---|---|
| WP230P | 10.8 | 0.38 | 1.78 | 1.0 |
| WP215N | 4.3 | 0.25 | 1.21 | 0.94 |
| WP215S | 2.5 | 0.14 | 0.796 | <MDL (0.68) |
| WP430N | 4.4 | 0.31 | 1.97 | <MDL (0.69) |
| WP430S | 2.1 | 0.14 | 0.895 | 0.69 |
| WP645N | 5.0 | 0.28 | 2.06 | <MDL (0.68) |
| WP1500N | 4.5 | 0.39 | 1.85 | 4.68 |
| WP230D | 1.3 | 0.10 | 0.445 | <MDL (0.64) |
| WPD215N | 3.0 | 0.11 | 0.681 | <MDL (0.73) |
| WPD215S | 3.6 | 0.23 | 3.33 | <MDL (0.64) |
| WPD430N | 4.1 | 0.11 | 0.367 | <MDL (0.63) |
| WPD430S | 2.3 | 0.27 | 2.43 | <MDL (0.65) |
| WPD1500N | 1.4 | 0.18 | 0.730 | 5.87 |
| WP280W | 11.2 | 0.45 | 2.60 | <MDL (0.70) |
| WPW215N | 5.1 | 0.33 | 1.77 | <MDL (0.70) |
| WPW215S | 4.3 | 0.29 | 0.918 | <MDL (0.67) |
| WPW430N | 5.2 | 0.27 | 0.536 | <MDL (0.69) |
| WPW645N | 3.9 | 0.35 | 0.933 | 1.1 |
| WPW1500N | 5.2 | 0.41 | 0.931 | <MDL (0.69) |

Arsenic was detected in 4 of 19 samples at concentrations ranging from 3.4 to 4.5 mg/Kg DW, very near the MDL range of 3.1 to 3.6 mg/Kg DW. The detected concentrations are all well below the arsenic SQS chemical criterion of 57 mg/Kg DW.

Cadmium was not detected in any of the samples. The MDL range of 0.19 to 0.22 mg/Kg DW is well below the SQS chemical criterion of 5.1 mg/Kg DW.

Lead was detected in 18 of 19 samples at concentrations ranging from 3.0 to 18.6 mg/Kg DW, all well below the SQS chemical criterion of 450 mg/Kg DW.

Mercury was detected in 12 of 19 samples at concentrations ranging from 0.026 to 0.13 mg/Kg DW. The highest detected mercury concentration of 0.13 mg/Kg is less than 35% of the SQS chemical criterion of 0.41 mg/Kg DW.

Silver was detected in one sample, at a concentration of 0.28 mg/Kg DW, which is very near the MDL range of 0.26 to 0.29 mg/Kg DW. The one detected concentration, as well as all of the MDLs, are well below the SQS chemical criterion of 6.1 mg/Kg DW.

### 4.2.3 Organics

Organic compounds regulated under SMS include polynuclear aromatic hydrocarbons, phthalates, chlorobenzenes, PCBs, acid/alcohol (ionic) compounds, and miscellaneous non-ionic organics. Data for the seven ionic compounds regulated under SMS are normalized to dry weight for comparison with SQS chemical criteria. Data for the remaining non-ionic organic compounds regulated under SMS are generally normalized to organic carbon for comparison with SMS chemical criteria. However, normalization to organic carbon can produce biased

results when the organic carbon content of the sample is very low (Ecology, 1992). When the organic carbon content of a sample is near 0.1 or 0.2% (1,000 to 2,000 mg/Kg DW), even background concentrations of certain organic compounds can exceed the SQS. TOC values in all 19 samples were less than 0.5%, therefore, all analytical results for non-ionic trace organics are presented in units of micrograms per kilogram on a dry weight basis (µg/Kg DW) and compared to LAET chemical criteria.

### *Polynuclear Aromatic Hydrocarbons (PAHs)*

One or more low-molecular weight PAH (LPAH) compounds were detected in 17 of 19 samples. LPAHs were not detected in the samples collected from Stations WP230D and WPD215N. Detected concentrations of individual LPAH compounds were all well below their associated LAET values. Total LPAH concentrations ranged from 3.1 to 687 µg/Kg DW, all well below the LAET value of 3,650 µg/Kg DW. The highest total LPAH concentration, detected at Station WP215N, is less than 20% of the LAET.

One ore more high-molecular weight PAH (HPAH) compounds were detected in 18 of 19 samples. HPAHs were not detected in the sample collected from Station WPD215N. Detected concentrations of individual HPAH compounds were all well below their associated LAET values. Total HPAH concentrations ranged from 21 to 4,060 µg/Kg DW, all well below the LAET value of 13,080 µg/Kg DW. The highest total HPAH concentration, also detected at Station WP215N, is less than 35% of the LAET.

### *Phthalates*

Benzyl butyl phthalate was detected in 7 of 19 samples at concentrations ranging from 7.20 to 13.3 µg/Kg DW, all less than 25% of the LAET value of 63 µg/Kg DW. Bis(2-ethylhexyl) phthalate was detected in all 19 samples at concentrations ranging from 9.4 to 52.9 µg/Kg DW, all less than 5% of the LAET value of 1,300 µg/Kg DW. Di-n-butyl phthalate was detected in all 19 samples, however, this compound was also detected in the associated laboratory quality control method blank. All of the reported di-n-butyl phthalate sample results were less than 10 times the concentration detected in the method blank and, therefore, should be considered as undetected. Di-n-octyl phthalate, diethyl phthalate, and dimethyl phthalate were not detected in any of the samples. Dry weight-normalized MDLs for all undetected phthalate compounds were well below their respective LAET values in all samples.

### *Chlorobenzenes*

Chlorobenzene compounds, including 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and hexachlorobenzene, were not detected in any of the samples. Dry weight-normalized MDLs for all four compounds were well below their associated LAET values in all samples.

### *Miscellaneous Non-Ionic Organic Compounds*

Dibenzofuran was detected in one sample, collected from Station WP215N, at a concentration of 2.8 µg/Kg DW. This detected value is well below the dibenzofuran LAET value of 140 µg/Kg DW. Hexachlorobutadiene and N-nitrosodiphenylamine were not detected in any of the samples. Dry-weight normalized MDLs for all three compounds were well below their associated LAET values in all samples.

### *Polychlorinated Biphenyls (PCBs)*

PCBs, as Aroclors®, were detected in 17 of 19 samples. Total PCB concentrations ranged from 1.7 to 78.7 µg/Kg DW, with the highest concentration detected at Station WPW645N. All of the detected total PCB concentrations are well below the associated LAET value of 130 µg/Kg DW – the highest detected concentration was approximately 60% of the LAET.

### *Ionic Organic Compounds*

Benzoic acid was detected in all 19 samples at concentrations ranging from 53.7 to 140 µg/Kg DW, all less than 35% of the SQS chemical criterion of 650 µg/Kg DW. Benzyl alcohol was detected in 13 of 19 samples at concentrations ranging from 5.3 to 28.2 µg/Kg DW, all less than 50% of the SQS chemical criterion of 57µg/Kg DW. Phenol was detected in all 19 samples at concentrations ranging from 7.0 to 133 µg/Kg DW, all less than 30% of the SQS chemical criterion. Pentachlorophenol, 2-methylphenol, 4-metholphenol, and 2,4-dimethylphenol were not detected in any of the samples. Dry weight-normalized MDLs for the four undetected phenolics compounds were well below their respective chemical criteria for all samples.

## Additional Organic Compounds

Additional organic analyses were performed on 9 of the 19 samples. These included chlorinated pesticides, chlorinated herbicides, organophosphorus pesticides, organotins, and polybrominated diphenyl ethers. Analytical results for these additional compounds are presented in units of µg/Kg DW and have been compared to LAET chemical criteria when available.

### *Chlorinated Pesticides*

Chlorinated pesticide analysis included the following 20 compounds. DDT and its metabolites DDD and DDE, Alpha-, Beta-, Delta, and Gamma-BHC, Alpha- and Gamma-Chlordane, Aldrin, Dieldrin, Endosulfan I, II, and Sulfate, Endrin and Endrin Aldehyde, Heptachlor and Heptachlor Epoxide, Methoxychlor, and Toxaphene. Eight of these compounds have associated LAET values; DDD, DDE, DDT, Aldrin, Alpha- and Gamma-Chlordane, Dieldrin, and Heptachlor. One compound, 4,4'-DDD, was detected in the sample collected from Station WP215N at a concentration of 0.63 µg/Kg DW. This concentration is less than 5% of the associated LAET value of 16 µg/Kg DW. This was the only pesticide detected in any of the nine samples. All dry weight-normalized pesticide MDLs were well below their associated LAET values in all nine samples.

### *Chlorinated Herbicides*

Chlorinated herbicide analysis included the following ten compounds: 2,4,5-T, 2,4-D, 2,4-DB, Dalapon, Dicamba, Dichloroprop, Dinoseb, MCPA, MCPP, and Silvex. Chlorinated herbicides were not detected in any of the samples. Dry weight-normalized MDLs for these compounds ranged from 0.68 to 6.6 µg/Kg DW.

### *Organophosphorus Pesticides*

Organophosphorus pesticide analysis included the following seven compounds: Chlorpyrifos, Diazinon, Disulfoton, Malathion; Ethylparathion, Methylparathion, and Phorate. Organophosphorus pesticides were not detected in any of the samples. Dry weight-normalized MDLs for these compounds ranged from 4.1 to 12 µg/Kg DW.

***Organotins***

Organotin analysis included four isomers of butyltin; mono-, di-, tri-, and tetra-n-butyltin. These four compounds were not detected in any of the samples. Dry weight-normalized MDLs for butyltin isomers ranged from: 11 to 12 µg/Kg DW (mono); 2.3 to 2.6 µg/Kg DW (di); 1.3 to 1.5 µg/Kg DW (tri); and 2.6 to 2.9 µg/Kg DW (tetra).

***Polybrominated Diphenyl Ethers (PBDEs)***

PBDE analysis included the following 14 congeners: TriBDE-17 and -28; TetraBDE-47, -66, and -71; PentaBDE-85, -99, and -100; HexaBDE-138, -153, and -154; HeptaBDE-183 and -190; and DecaBDE-209. One or more PBDE congeners were detected in all nine samples, with summed PBDE concentrations of the 14 congeners measured ranging from 0.480 to 3.18 µg/Kg DW. The average PBDE concentration for all stations sampled was 1.28 µg/Kg DW.

PBDE concentrations in Puget Sound sediments have not been widely studied. An Ecology study conducted in 2005 at 10 locations in Puget Sound found concentrations of PBDEs (12 congeners) similar to those detected proximal to the West Point outfall (Dutch and Aasen, 2007). King County monitored PBDE concentrations at an ambient site off Point Wells, which will be the future location of the Brightwater wastewater treatment plant. Total PBDE (14 congeners) concentrations detected in 11 stations collected from the Point Wells site ranged from 1.59 to 2.59 µg/Kg DW with a mean value of 2.05 µg/Kg DW (King County 2007). The range of concentrations detected at Point Wells are also similar to those concentrations detected at West Point.

## 4.2.4 Benthic Community Structure

Benthic infauna analysis was conducted on 11 sediments samples: 10 samples surrounding the end and mid-point of the diffuser and 1 sample north of the outfall (WP1500N) (see Figure 4-1). A complete list of all species identified and enumerated during the 2006 West Point sediment monitoring event is included in Appendix B. There are several indices that can be used to evaluate benthic community assemblages and compare results from sampling stations to one another. These indices include:

- Total Abundance, which is the number of individual organisms per 0.1 $m^2$;
- Total Richness, which is the number of species per 0.1 $m^2$ (the area sampled by a standard van Veen grab sampler);
- Total Biomass, which is the combined mass (weight) of all organisms found in a 0.1 $m^2$ sample;
- Shannon-Wiener Diversity Index (*H'*), which is a measure of the relationship between taxa richness and abundance;
- Pielou's Evenness Index (*J*), which is expressed as the observed diversity in a sample as a proportion of the maximum possible diversity; and
- Swartz's Dominance Index, which is defined as the minimum number of species comprising 75% of the total abundance in a given sample.

All of these indices have been calculated based on averages over the three replicate samples collected from each station.

## Abundance

Total abundance ranged from a low of 162 individuals, found at station WPD430N, to a high of 814 individuals, found at station WPW215S. The average abundance value was 472 individuals. Annelids represented the largest proportion of individual organisms at 10 of the 11 stations monitored. Figure 4-2 presents the average total abundance for the stations at which benthic data were collected. The figure shows that four stations clustered around the end of the outfall diffuser (WP230P, WPW215S, WPW215N, and WP215N) had the highest average total abundance. It should be noted that the higher abundance at these four stations was not due to an over-abundance of polychaete or other pollution-tolerant species. Polychaetes of the family Capitellidae, traditional indicators of organic enrichment or pollution, were present at only one station with only two individuals found.

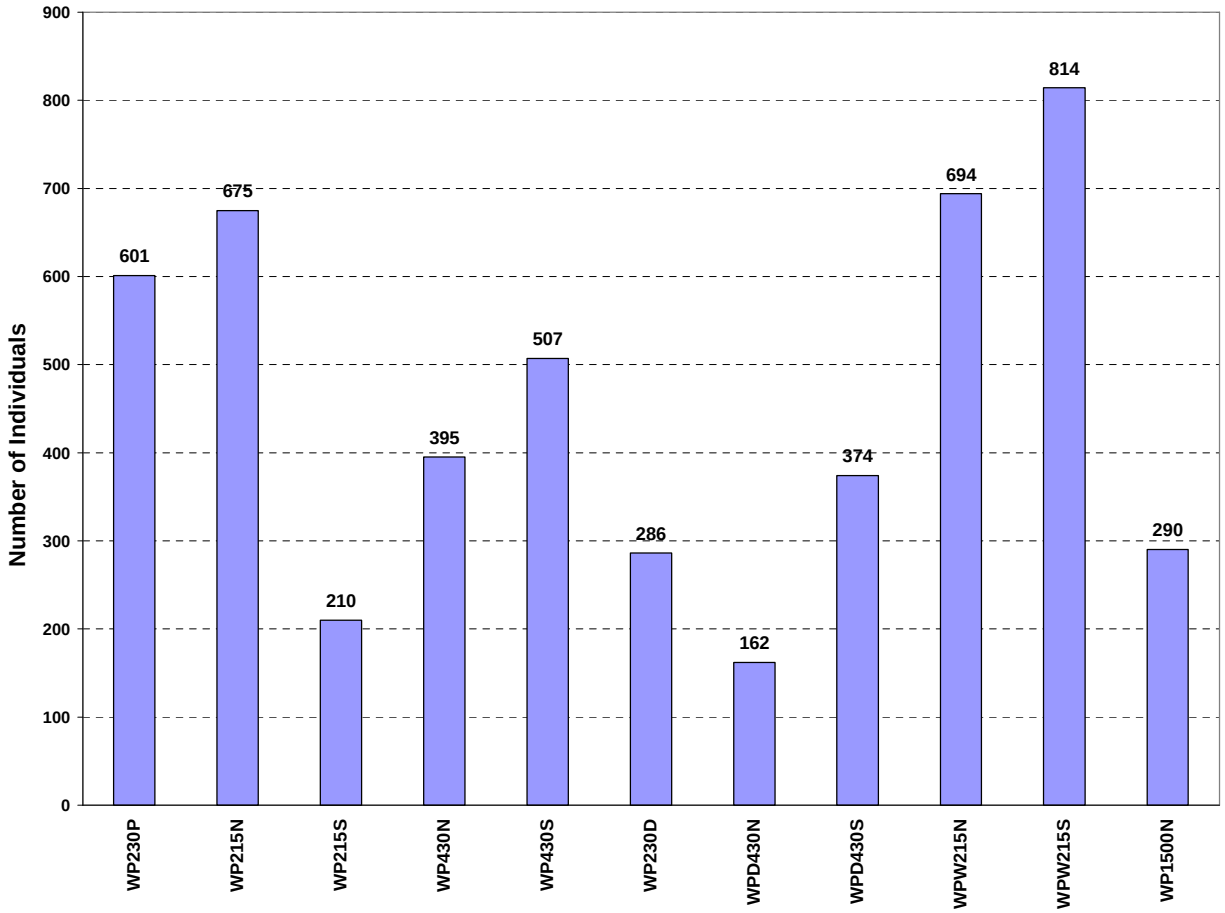


**Figure 4-2.** 2006 Average Abundance at the West Point TP

## Richness

Total richness ranged from a low of 64 different species, found at station WPD430N, to a high of 149 species, found at station WP215N. The average richness value was 125 species. Annelida taxa represented the highest number of species found at each monitoring station, ranging from 35 to 90 different species. Crustacean taxa represented the second highest number of different species at each station. Figure 4-3 presents the relative distribution of total richness for the stations at which benthic data were collected. The figure shows that average total richness values are similar for those stations clustered around the end of the outfall diffuser. Slightly lower average total richness values are exhibited at two stations north of the outfall along the mid-diffuser transect.

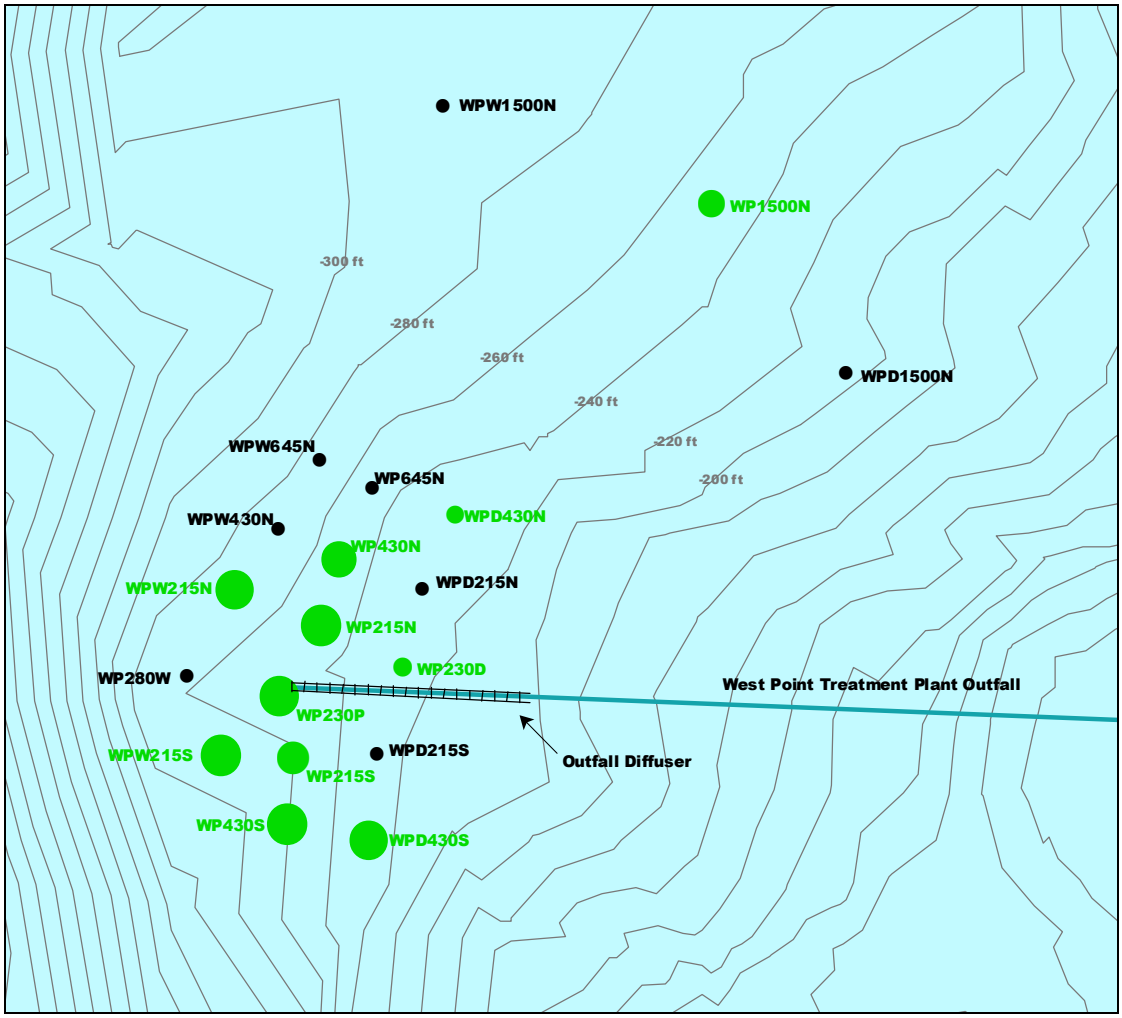


**Figure 4-3.** Distribution of Average Benthic Richness Values (size of dot is proportional to total abundance)

## Biomass

Total biomass is expressed in grams per 0.1 square meter (g/0.1 $m^2$). Reported total biomass measurements at the 16 stations ranged from 3.72 to 16.45 g/0.1 $m^2$. The average biomass value was 9.57 g/0.1 $m^2$. Although always measured, total biomass is not a particularly useful comparative tool for assessing benthic community assemblages, given confounding factors such as differences in shell or carapace size or the presence of one large individual in a sample.

## Diversity Indices

Diversity indices calculated for the benthic data included the Shannon-Wiener Diversity Index, Pielou's Evenness Index, and Swartz's Dominance Index. These diversity indices were also calculated from the averages of three replicates at each station.

### *Shannon-Wiener Diversity Index*

The Shannon-Wiener Diversity Index (*H'*) is one of the most widely-used diversity indices due to its ease of calculation and its relative independence of sample size. This index uses the total number of species in a sample as well as the abundances of single species to determine diversity. Increasing index values indicate increasing diversity of the benthic community. *H'* values ranged from a low of 2.01 at station WPD430N to a high of 7.29 at station WPW215S. The average *H'* value was 4.97.

### *Pielou's Evenness Index*

Pielou's Evenness Index (*J*) is another measure of diversity that is commonly used in conjunction with the Shannon-Wiener Diversity Index. Evenness is a measure of the observed diversity in a sample as a proportion of the maximum possible diversity. *J* values close to 1.0 represent a sample composed of many different species while low *J* values indicate a sample composed of only a few dominant species. *J* values ranged from a low of 0.34 at station WPD430N to a high of 1.01 at station WPW215S. The average *J* value was 0.71.

### *Swartz's Dominance Index*

Swartz's Dominance Index (SDI) measures the minimum number of species whose abundance comprises 75% of the total sample abundance. Low values indicate a sample with little diversity while higher numbers indicate a sample comprised of many species. SDI values ranged from a low of 10 at station WPD430S to a high of 64 at station WP230P. The average SDI value was 48. There was no one dominant species evident at all 11 stations, rather a rich mixture of species including some pollution-sensitive species, such as *Cucumaria piperata*.

Table 4-4 provides a summary of the diversity indices for all stations sampled.

**Table 4-4.** Diversity Indices Summary for West Point Stations

| Station | Shannon-Wiener Diversity Index | Pielou's Evenness Index | Swartz's Dominance Index |
|---|---|---|---|
| **WP230P** | 6.12 | 0.85 | 64 |
| **WP215N** | 6.43 | 0.89 | 56 |
| **WP215S** | 2.53 | 0.39 | 54 |
| **WP430N** | 4.41 | 0.63 | 63 |
| **WP430S** | 4.91 | 0.72 | 41 |
| **WP230D** | 3.08 | 0.50 | 45 |
| **WPD430N** | 2.01 | 0.34 | 47 |
| **WPD430S** | 6.45 | 0.90 | 10 |
| **WPW215N** | 6.44 | 0.90 | 50 |
| **WPW215S** | 7.29 | 1.01 | 48 |
| **WP1500N** | 3.29 | 0.50 | 54 |

## 4.3 2007 Ambient Offshore Sediments

Marine sediment was collected from 14 ambient stations in June 2007 (see map in Section 2). Three stations were located in the Central Basin: near Point Jefferson (KSBP01); off of West Seattle (LSML01); and in East Passage (NSEX01). These three stations are all deep and removed from direct anthropogenic inputs.

Three stations were located in shallow embayments; outer Salmon Bay (KSRU03); Fauntleroy Cove (LSVV01); and inner Quartermaster Harbor (MSVK01). These three embayments all have anthropogenic inputs that could impact sediment quality. Station KSRU03 is located on the marine side of the Hiram M. Chittenden locks and receives a high level of both small and large vessel traffic entering and exiting the locks. Station LSVV01 is located near the Fauntleroy/Vashon ferry dock. This area has a history of water quality issues, receives a large amount of freshwater input, and is impacted by ferry traffic. Station MSVK01 is located in a shallow, quiescent embayment that receives a moderate amount of seasonal small vessel traffic

Eight stations were located in Elliott Bay and represent a combination of moderately shallow to deep stations in the center of the bay. Four of the Elliott Bay stations have long-term sediment quality data sets and form a rough east-west transect away from locations of potential point-source impacts to the sediment:

LTDF01 located along the central Seattle waterfront, near Pier 66,
LTED04 located in the center of Elliott Bay,
LTCA02 located in the center of Elliott Bay, west of LTED04, and
LSCW02 located at the hypothetical boundary between Elliott Bay and the Central Basin.

Four new Elliott Bay stations were added to the monitoring program in 2007 to assess specific areas of the bay. These stations are:

KSZY01 located just offshore of Piers 90/91. This area has historically received high heavy-vessel traffic and will continue to receive large ships when cruise liners begin using these docking facilities.
LTAA02 located just offshore of the grain terminal. This area has also historically received high large-vessel traffic.
LTGF01 located just offshore of the northern end of Harbor Island. This location is in an area of heavy industry, including fuel storage and transfer, shipbuilding and repair, and the transportation industry.
LSHZ08 located just offshore of Cove 2 at Seacrest Park. This area has high usage by recreational SCUBA divers, including diving classes, which includes a high incidence of primary contact with bottom sediments, especially by student divers.

Samples were analyzed for conventional sediment parameters, metals, and organic compounds.

## 4.3.1 Sediment Conventionals

Sediment conventional analyses included grain size distribution, total organic carbon, ammonia nitrogen and total sulfides.

### *Grain Size Distribution*

Grain size distribution varied widely between the 14 sampling stations. Figure 4-4 shows the percent grain size distribution in the four major size-groupings; gravel, sand, silt, and clay. The silt plus clay fractions represent the percent fines content of a sediment sample. Percent fines ranged from a low of 4.0% at Station LSVV01 (Fauntleroy Cove) to a high of 96.0% at Station NSEX01 (East Passage). The three deep main basin stations exhibited differing grain size distributions with percent fines content of 15.5% at KSBP01 (Point Jefferson); 61.5% at Station LSML01 (West Seattle), and 96.0% at Station NSEX01. Of note is the very low percent fine content of 4.0% at Station LSVV01. The prop wash from the Fauntleroy/Vashon ferry as it arrives, departs, and idles may cause the removal of fine material at this station.

### *Total Organic Carbon*

Total organic carbon concentrations ranged from 1,850 to 24,700 mg/Kg DW or, approximately, 0.2 to 2.5%. Total organic carbon correlated well with percent fine material, as shown in Figure 4-5.

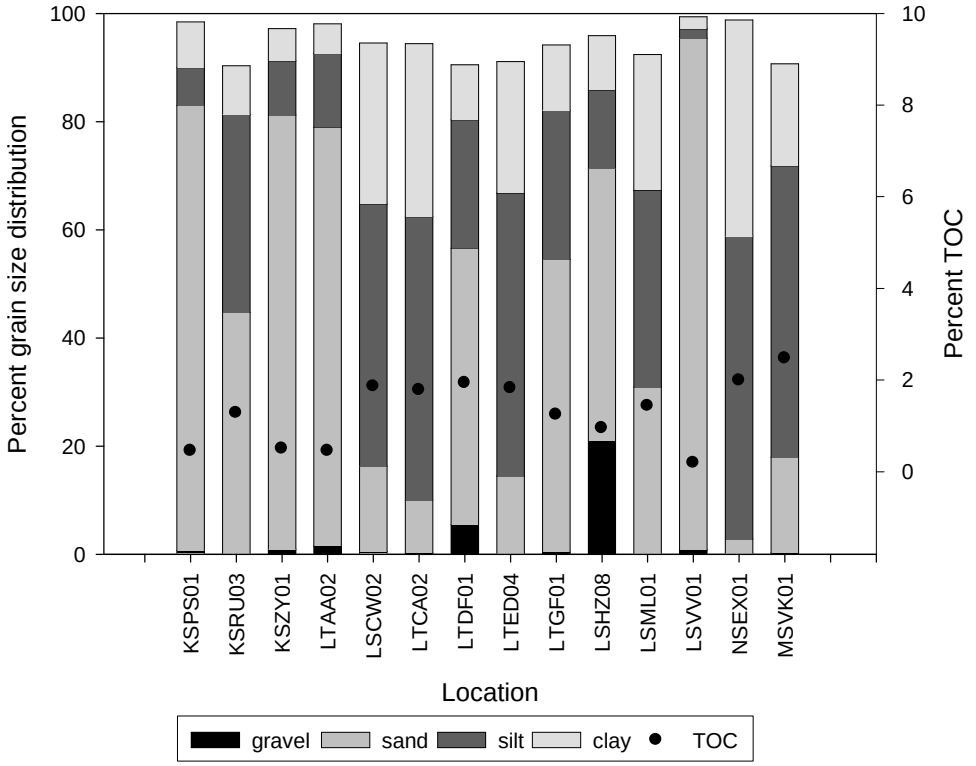


**Figure 4-4.** Grain Size Distribution and Total Organic Carbon for Ambient Stations

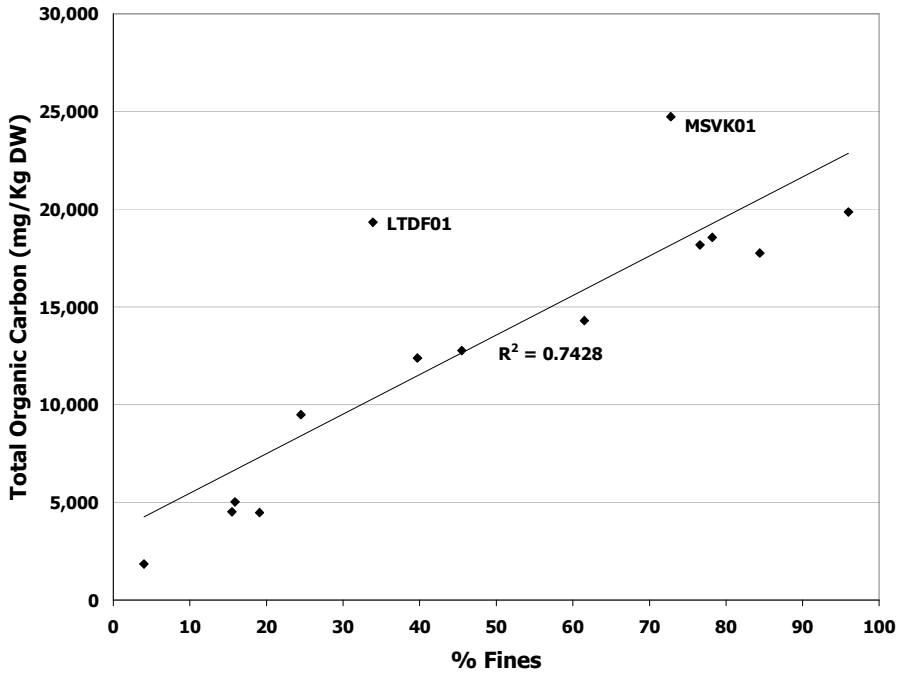


**Figure 4-5.** Total Organic Carbon vs. Percent Fines for All Stations

Two exceptions to this correlation appear to be at Station MSVK01 in Quartermaster Harbor and Station LTDF01 along the central Seattle waterfront, both of which exhibited somewhat higher total organic concentrations relative to the percent fine material found in the samples. One explanation for the higher organic carbon concentration at Station MSVK01 may be from the settlement/sedimentation of decaying phytoplankton. A large phytoplankton bloom was recorded in Quartermaster Harbor during June 2007, the month in which the sediment sample was collected (see Section 3). The higher organic carbon concentration at Station LTDF01 may also have been the result of a phytoplankton bloom, although the bloom appeared to be of smaller magnitude in Elliott Bay. Anthropogenic inputs of organic carbon may also be present at this station, given its proximity to the waterfront shoreline.

### *Ammonia and Sulfide*

Sediment ammonia concentrations ranged from 1.67 to 20.3 mg/Kg DW and correlated well with percent fine material, as shown in Figure 4-6.

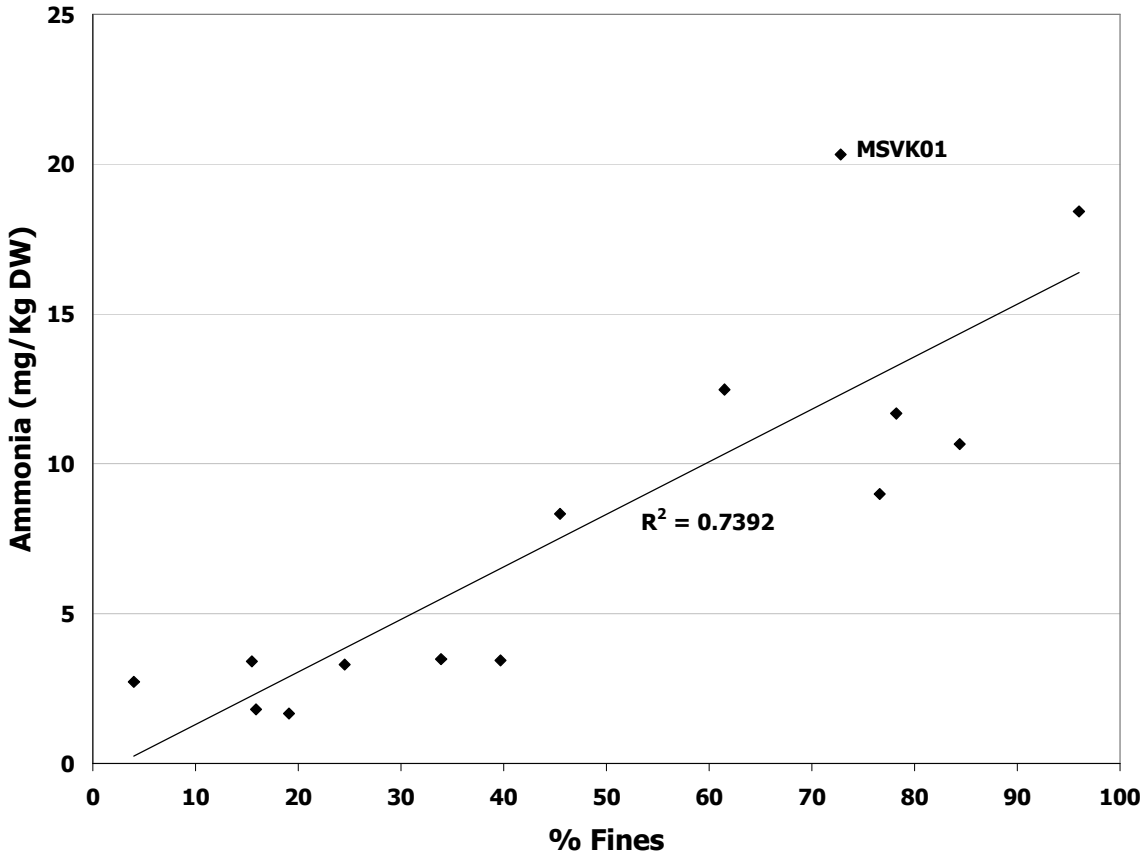


**Figure 4-6.** Sediment Ammonia Concentration vs. Percent Fines for All Stations

The exception to this correlation appears to be at Station MSVK01 in Quartermaster Harbor, which exhibited a somewhat higher ammonia concentration relative to the percent fine material found in the sample. One explanation for the higher ammonia concentration at this station may be from bacterial decay and settlement/sedimentation of phytoplankton or from zooplankton excretions during phytoplankton grazing during the large June 2007 bloom in Quartermaster Harbor.

Total sulfide was detected in 9 of 14 samples, at concentrations ranging from 1.49 to 562 mg/Kg DW. There was no apparent correlation between total sulfide concentration and any other measured conventional parameter, nor did there appear to be any distinct spatial patterns to total sulfide concentrations.

### 4.3.2 Metals

Sediment metals analysis included 14 metals: the eight metals regulated under the Sediment Management Standards (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc); three additional trace metals (antimony, nickel, and tin); and three crustal metals (aluminum, iron, and manganese). The crustal metals were analyzed to provide a method for normalizing trace metal concentrations as a means to evaluate possible anthropogenic inputs. All metals results are presented in units of mg/Kg DW.

Table 4-5 presents results for the 14 metals analyzed, providing the frequency of detection (FOD) along with the minimum, maximum, and median concentrations. The table also compares those concentrations to the Sediment Quality Standard (SQS) chemical criteria for the eight metals regulated under the Sediment Management Standards.

**Table 4-5.** Sediment Metals Concentrations (mg/Kg DW)

| Metal | FOD | Minimum | Maximum | Median | SQS |
|---|---|---|---|---|---|
| Aluminum | 14/14 | 5,690 | 20,800 | 12,050 | -- |
| Antimony | 0/14 | -- | -- | -- | -- |
| Arsenic | 14/14 | 2.26 | 22.6 | 8.07 | 57 |
| Cadmium | 10/14 | 0.18 | 1.90 | 0.36 | 5.1 |
| Chromium | 14/14 | 17.1 | 61.7 | 34.5 | 260 |
| Copper | 14/14 | 4.25 | 81.2 | 45.1 | 390 |
| Iron | 14/14 | 8,860 | 30,000 | 23,100 | -- |
| Lead | 14/14 | 5.94 | 63.7 | 31.7 | 450 |
| Manganese | 14/14 | 150 | 591 | 307 | -- |
| Mercury | 14/14 | 0.013 | 0.569 | 0.177 | 0.41 |
| Nickel | 14/14 | 14.5 | 38.3 | 30.2 | -- |
| Silver | 13/14 | 0.41 | 1.07 | 0.72 | 6.1 |
| Tin | 9/14 | 2.07 | 6.08 | 3.35 | -- |
| Zinc | 14/14 | 20.4 | 98.5 | 83.4 | 410 |

Mercury was the only metal that exceeded an SQS chemical criterion. The mercury concentration of 0.458 mg/Kg DW at Station MSVK01 (Quartermaster Harbor) and 0.569 mg/Kg DW at Station LTGF01 (Harbor Island) both exceeded the SQS criterion of 0.41 mg/Kg DW. Both concentrations, however, were below the mercury Cleanup Screening Level (CSL) chemical criterion of 0.59 mg/Kg DW.

Metals results generally correlated well with both percent fines and crustal metals. Figure 4-7 shows a sampling of these correlations in the graphs of percent fines versus six metals; arsenic, chromium, copper, lead, mercury, and zinc. The correlation graphs were similar when normalizing trace metals to both aluminum and iron as well. These correlations, however, also point out what appear to be some elevated concentrations of specific metals relative to percent fines.

Station MSVK01 in Quartermaster Harbor appears to have elevated concentrations of arsenic, copper, lead, and mercury. Although not shown in Figure 4-7, Station MSVK01 also had an elevated concentration of cadmium, relative to the other stations. Stack emissions from the Asarco smelter may have lead to these increased concentrations of arsenic, lead, cadmium, and mercury in Quartermaster Harbor. An explanation for the elevated sediment copper concentration is not apparent. The remaining elevated metals concentrations shown in Figure 4-7 are all at stations in Elliott Bay, where there are numerous point and non-point sources of metals.

### 4.3.3 Organics

Organic compounds analyzed in sediment samples included polynuclear aromatic hydrocarbons, phthalates, chlorobenzenes, polychlorinated biphenyls, chlorinated pesticides, butyltins, total 4-nonylphenol, polybrominated diphenyl ethers, and other, miscellaneous semivolatile organic compounds.

All organic compound results are presented in units of μg/Kg DW. The Washington State Sediment Managements standards normalize organic results for 30 compounds to total organic carbon for regulatory purposes. This normalization is generally done when the organic carbon content of the sediment sample is greater than 5,000 mg/Kg DW or 0.5%. When the organic carbon content of the sample is less than 0.5%, results for these 30 compounds are normalized to dry weight (Ecology, 1992). These dry weight normalized results are compared to Puget Sound Lowest Apparent Effects Threshold (LAET) values (EPA, 1988) as a measure of sediment quality.

Total organic carbon concentrations in the 14 samples were both below and above the 0.5% organic carbon normalization threshold. For comparative purposes in this narrative, all results have been normalized to dry weight and evaluated against LAET values. When a LAET value has been exceeded, the result, if appropriate, has also been normalized to organic carbon and compared to the Sediment Management Standards SQS and/or CSL criteria.

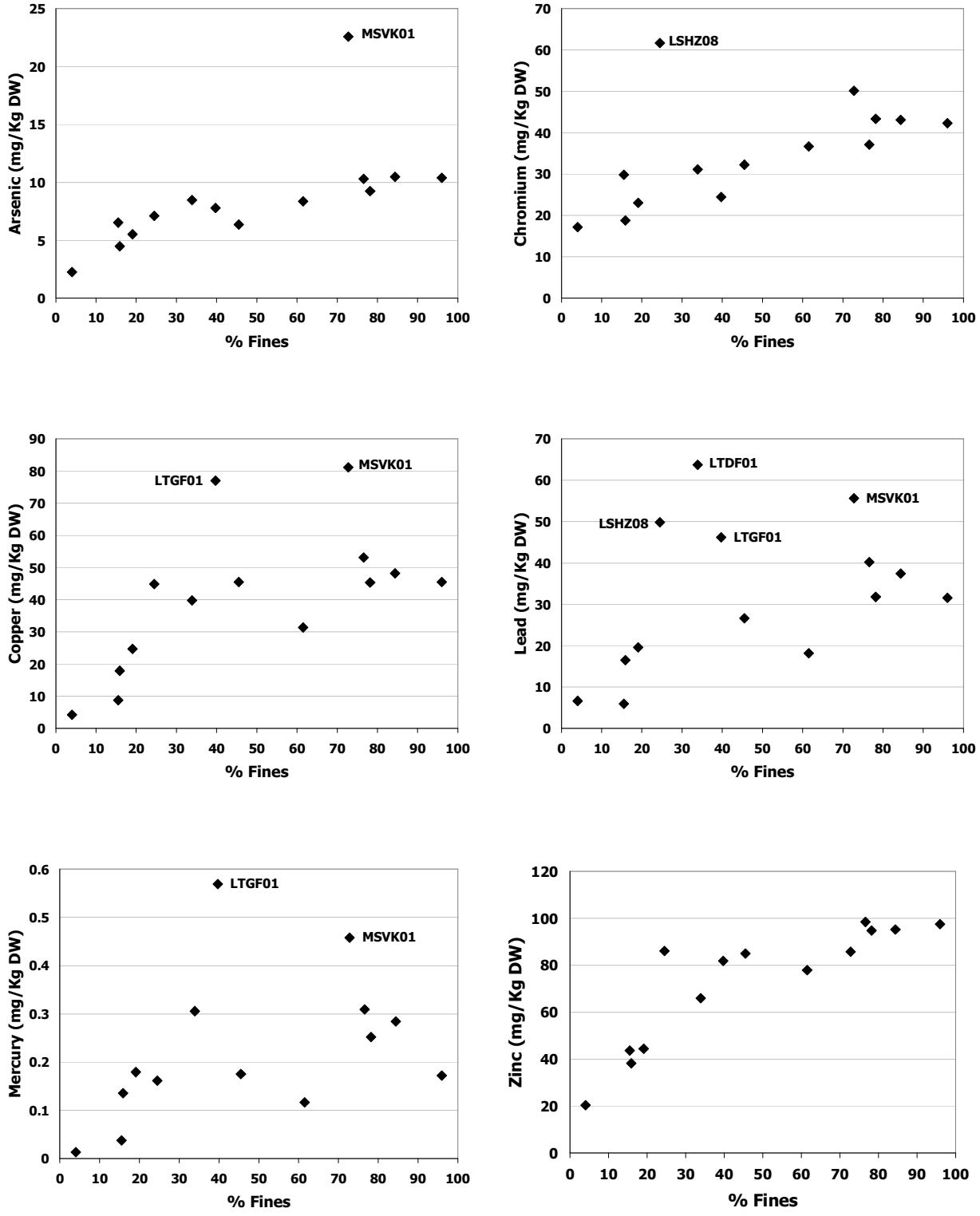


**Figure 4-7.** Six Sediment Metals Normalized to Percent Fines

### *Polynuclear Aromatic Hydrocarbons (PAHs)*

Polynuclear aromatic hydrocarbons (PAHs) are hydrocarbon compounds that include multiple benzene rings. These compounds are components of asphalts, fuels, oils, and creosote. Creosote, a compound commonly used on pilings as a wood preservative to deter marine boring organisms, is comprised of up to 80% PAHs (Hutton and Samis, 2000). PAHs are also created through the incomplete or low-temperature combustion of carbon-containing materials such as oil, wood, and coal. Automobile exhaust and industrial emissions also can contain high levels of PAHs. PAHs can enter the marine environment from direct contact with PAH-containing products (creosote, spills) or through stormwater runoff from roadways.

PAH analysis included both low molecular weight PAHs (LPAHs) and high molecular weight PAHs (LPAHs). Due to their higher molecular weight, HPAH compounds tend to be more persistent in the environment. A number of HPAH compounds are also considered to be carcinogenic. A total of 17 PAH compounds (7 LPAHs and 10 HPAHs) were analyzed.

Total LPAH concentrations ranged from 7.84 to 766 µg/Kg DW, all of which are below the LAET value of 1,200 µg/Kg DW. Total HPAH concentrations ranged from 47 to 5,340 µg/Kg DW, also all below the LAET value of 7,900. No individual LPAH or HPAH compound exceeded its respective LAET value. Figure 4-8 shows the range of Total PAHs (the sum of LPAH and HPAH concentrations) detected in the 14 samples.

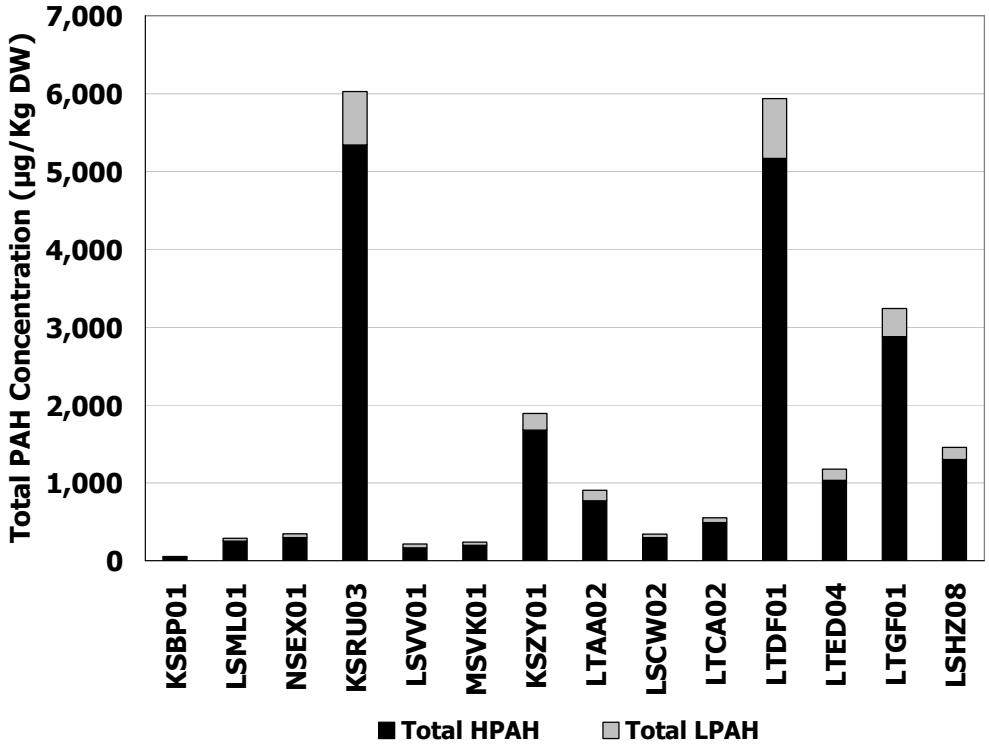


**Figure 4-8.** Total PAH Sediment Concentrations

Total PAH concentrations ranged from 55 to 6,030 μg/Kg DW. As shown in Figure 4-8, the lowest total PAH concentrations were found at the three deep, main basin stations and two of the three embayment stations, LSVV01 (Fauntleroy Cove) and MSVK01 (Quartermaster Harbor). With the exception of Station LSVV01, these five sampling locations are removed from any direct PAH sources. Although proximal to the Fauntleroy/Vashon dock, which has creosoted pilings, the lack of fine material present in the sediments at Station LSVV01 appears to preclude the accumulation of elevated PAH concentrations. Station KSRU03, located in outer Salmon Bay, had the highest total PAH concentration. This sampling station, located on the marine side of the Hiram M. Chittenden locks is surrounded by many creosoted pilings and wing walls. The second highest total PAH concentration was detected at Station LTDF01, along the central Seattle waterfront. This station is in an area of both current and historic sources of creosote as well as receiving street runoff from many storm drains and combined sewer overflows that line the waterfront's seawall. All of the other higher concentrations in Elliott Bay were detected at stations near shorelines and, as such, in closer proximity to pilings and sources of storm water runoff.

### *Phthalates*

Phthalates, widely used as plasticizers, are ubiquitous in the environment, entering marine waters from both point and nonpoint sources. In addition to being ubiquitous in the environment, phthalates are common sampling and laboratory contaminants. Phthalate analysis included the six phthalates regulated under the Washington State Sediment Management Standards. Three phthalates were detected in all 14 samples. Table 4-6 provides the minimum, median, and maximum concentrations for benzyl butyl phthalate, bis(2-ethylhexyl) phthalate, and di-N-butyl phthalate, compared to their respective LAET values.

**Table 4-6.** Sediment Phthalate Concentrations (μg/Kg DW)

| Phthalate | Minimum | Median | Maximum | LAET |
|---|---|---|---|---|
| Benzyl Butyl Phthalate | 14.8 | 31.6 | 75.9 | 63 |
| Bis(2-ethylhexyl) Phthalate | 19.8 | 74.1 | 3,390 | 1,300 |
| Di-N-butyl Phthalate | 8.1 | 18.5 | 29.5 | 58 |

The benzyl butyl phthalate concentration of 75.9 μg/Kg DW detected at Station LTGF01 (Harbor Island) exceeded the LAET value of 63 μg/Kg DW. When normalized to organic carbon, the concentration becomes 6.13 mg/Kg OC, which also exceeds the SQS criterion of 4.9 mg/Kg OC but is below the CSL criterion of 64 mg/Kg OC. The benzyl butyl phthalate concentrations detected at the other 13 stations ranged from 14.8 to 48.1 μg/Kg DW, all below the LAET value.

The bis(2-ethylhexyl) phthalate concentration of 3,390 μg/Kg DW detected at Station NSEX01 (East Passage) significantly exceeded the LAET value of 1,300 μg/Kg DW. When normalized to organic carbon, the concentration becomes 171 mg/Kg OC, which exceeds the CSL criterion of 78 mg/Kg OC. There is not an apparent source of this phthalate at this deep, main basin station.

The bis(2-ethylhexyl) phthalate concentrations detected at the other 13 stations ranged from 19.8 to 506 μg/Kg DW, all well below the LAET value.

The di-N-butyl phthalate concentrations detected at all 14 stations ranged from 8.1 to 29.5 μg/Kg DW, which are all well below the LAET value of 58 μg/Kg DW.

Dimethyl phthalate was detected only at Station KSRU03 (Outer Salmon Bay) at a concentration of 11 μg/Kg DW, which is below the LAET value of 71 μg/Kg DW. Di-N-octyl phthalate and diethyl phthalate were not detected at any of the 14 stations.

### *Chlorobenzenes*

Analysis of chlorobenzene compounds included 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and hexachlorobenzene. 1,4-Dichlorobenzene, a common compound found in mothballs and urinal deodorant cakes, was the only chlorobenzene detected. It was detected in a single sample, collected from Station LTDF01 (Seattle Waterfront) at a concentration of 1.88 μg/Kg DW, which is below the LAET value of 81 μg/Kg DW.

### *Polychlorinated Biphenyls (PCBs)*

PCBs were formerly used widely, due to their insulating and cooling properties, as dielectric fluids in electrical transformers and capacitors, as lubricants, as additives in flexible PVC wire casings, and in hydraulic fluid. Although PCB manufacturing was banned in the United States in 1977, they are still present in some older electrical equipment and can still be released to the environment. The chemical structure of PCBs make them very persistent in the environment, especially in fine-grained sediments. PCBs are classified as persistent and bioaccumulative and have been demonstrated to be toxic to marine life.

PCBs (as total Aroclors®) were detected in 13 of 14 samples. Total PCB concentrations in the three samples collected from Central Basin stations – KSBP01, LSML01, and NSEX01 - ranged from 1.45 to 5.02 μg/Kg DW. These PCB concentrations, at stations removed from direct anthropogenic influence, correlated well with the percent fine material present in the samples.

PCBs were not detected in the sample collected from Station LSVV01 (Fauntleroy Cove), which is likely due to the very small proportion of fine material – less than 5% silts and clays – in the grain size distribution at this station. Total PCB concentrations in the two other samples collected from embayments were 5.71 μg/Kg DW at Station MSVK01 (Quartermaster Harbor) and 33.1 μg/Kg DW at Station KSRU03 (Outer Salmon Bay).

Total PCB concentrations in the eight samples collected from Elliott Bay ranged from 21.5 to 156 μg/Kg DW. The total PCB concentrations of 144 μg/Kg DW at Station LTGF01 (Harbor Island) and 156 μg/Kg DW at Station LTDF01 (Central Waterfront) exceeded the LAET value of 130 μg/Kg DW. When appropriately normalized to organic carbon, however, these concentrations became 11.6 and 8.06 mg/Kg OC, respectively, neither of which exceeded the SQS criterion of 12 mg/Kg OC. Figure 4-9 shows the relative concentrations of total PCBs between the Central Basin (black), Elliott Bay (hatched), and embayment (gray) stations.

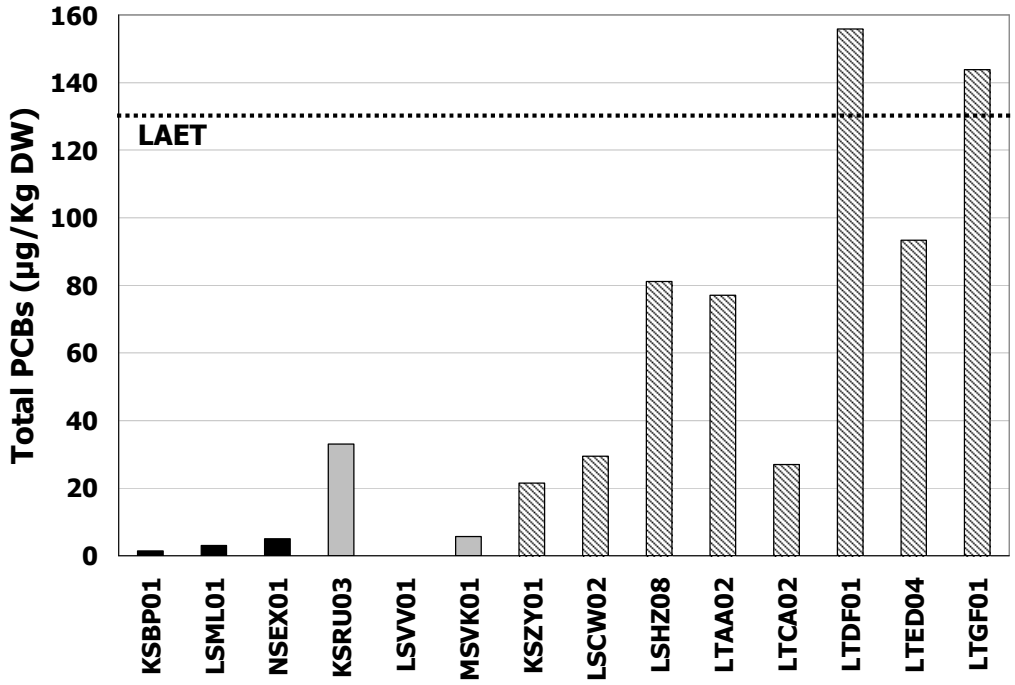


**Figure 4-9.** Total PCB Sediment Concentrations at Central Basin, Embayment, and Elliott Bay Stations

### *Chlorinated Pesticides*

Chlorinated pesticide analysis included 20 compounds, most of which are not in use today. Due to their persistent nature, however, many are still found in the environment and are considered to be toxic and bioaccumulative. Of the 20 compounds analyzed, only three were detected. The pesticide DDT and its metabolites DDD and DDE were detected at three stations. DDT was detected at a concentration of 4.73 µg/Kg DW at Station KSRU03, in outer Salmon Bay. DDT was also detected at Station LTGF01, near Harbor Island, at a concentration of 2.0 µg/Kg DW. DDD, DDE, and DDT were all detected at Station LTDF01, along the Central Waterfront, at concentrations of 3.66, 4.09, and 25.4 µg/Kg DW, respectively. These three concentrations report as a Total DDT concentration of 32.8 µg/Kg DW. The total DDT concentration of 32.8 µg/Kg DW reported at Station LTGF01 exceeds the LAET value of 11 µg/Kg DW.

### *Butyltins*

Butyltins, especially the isomer tributyltin, were used extensively as an anti-fouling agent in boat paints due to their effectiveness in preventing the attachment of marine organisms, particularly barnacles and algae, to boat hulls. However, tributyltin is also toxic to non-target marine organisms and its use was banned in 1998 on leisure craft. It is still used as a component in anti-fouling paints for commercial vessels. Butyltins can enter the environment both passively, through general degradation of hull paint, or actively, during routine maintenance of vessel hulls, when sandblasting of old paint directly introduces the grit to the marine environment.

Butyltin analysis included four isomers of the organotin; mono-n-, di-n-, tri-n-, and tetra-n-butyltin. Monobutyltin and tetrabutyltin were not detected in any of the samples. Dibutyltin and tributyltin were detected in three samples, all located in areas associated with heavy commercial vessel traffic and/or hull maintenance. The three detected concentrations (sum of dibutyltin and tributyltin) were:

- Station KSRU03 – 37.7 μg/Kg DW. This station is located in outer Salmon Bay on the marine side of the Hiram M. Chittenden locks and receives heavy commercial marine vessel traffic.
- Station LTDF01 – 29.1 μg/Kg DW. This station is located along the central Seattle waterfront, near the Bell Harbor Marine and also receives heavy commercial marine vessel traffic.
- Station LTGF01 – 123 μg/Kg DW. This station is located at the north end of Harbor Island, which is an area of both heavy commercial marine vessel traffic and vessel maintenance drydocks.

Tributyltin alone was detected at a concentration of 4.3 μg/Kg DW at Station KSHZ08, located near Cove 2 at Seacrest Park, on the west side of Elliott Bay.

### *Total 4-Nonylphenol*

Total 4-nonylphenol was analyzed as a surrogate for alkyl phenols, which are widely used in plastics and as surfactants. Nonylphenols, used as surfactants in many detergents, are widely released to the environment, both from point and non-point sources. Total 4-nonylphenol was detected in 4 of 14 samples – collected from stations KSBP01 (Point Jefferson), KSRU03 (Outer Salmon Bay), LSCW02 (Outer Elliott Bay), and LTCA02 (Central Elliott Bay)–at concentrations ranging from 31.9 to 69.3 μg/Kg DW. The detection limits for the 10 samples in which total 4-nonylphenol was not detected ranged from 6.7 to 18 μg/Kg DW. There was no apparent correlation between total 4-nonylphenol concentration and either percent fine material or organic carbon concentration. There was also no apparent pattern of spatial distribution with respect to potential sources of nonylphenols. Currently, there are no regulatory criteria for nonylphenols in marine sediment, however, the Canadian government has an interim sediment quality guidance value of 1,400 μg/Kg DW, which is based on a threshold effects level (Environment Canada, 2005).

### *Polybrominated Diphenyl Ethers (PBDEs)*

Polybrominated diphenyl ethers (PBDEs) are widely used as flame retardants and can enter the environment from both point and nonpoint sources. PBDEs can be found in 209 different chemical forms, or congeners. Samples were analyzed for 14 PBDE congeners, including tri-, tetra-, penta-, hexa-, hepta-, and decaBDEs. PBDEs were detected in every sample. The sum of detected congeners ranged from 1.68 to 15.1 μg/Kg DW in the 14 samples. It should be noted that the sum of congeners does not represent a total PBDE concentration since only 14 out of 209 congeners were analyzed. There was no apparent correlation between PBDE concentrations and either percent fines or total organic carbon. Figure 4-10 shows the relative PBDE concentrations (sum of 14 congeners) between the Central Basin, embayment, and Elliott Bay stations.

The PBDE concentration of 15.1 µg/Kg DW detected in the sample collected from Station KSRU03 (outer Salmon Bay) may be the result of the station's proximity to the locks and the high level of boat traffic in the area. PBDEs are used as a flame retardant in most personal flotation devices (PFDs), which, over time can become friable and enter the marine environment.

King County also evaluated sediment PBDE concentrations at its West Point Treatment Plant outfall and the location of the future Brightwater Treatment Facility outfall. Average PBDE concentrations for the same 14 congeners at these two sites were 1.59 and 2.05 µg/Kg DW, respectively.

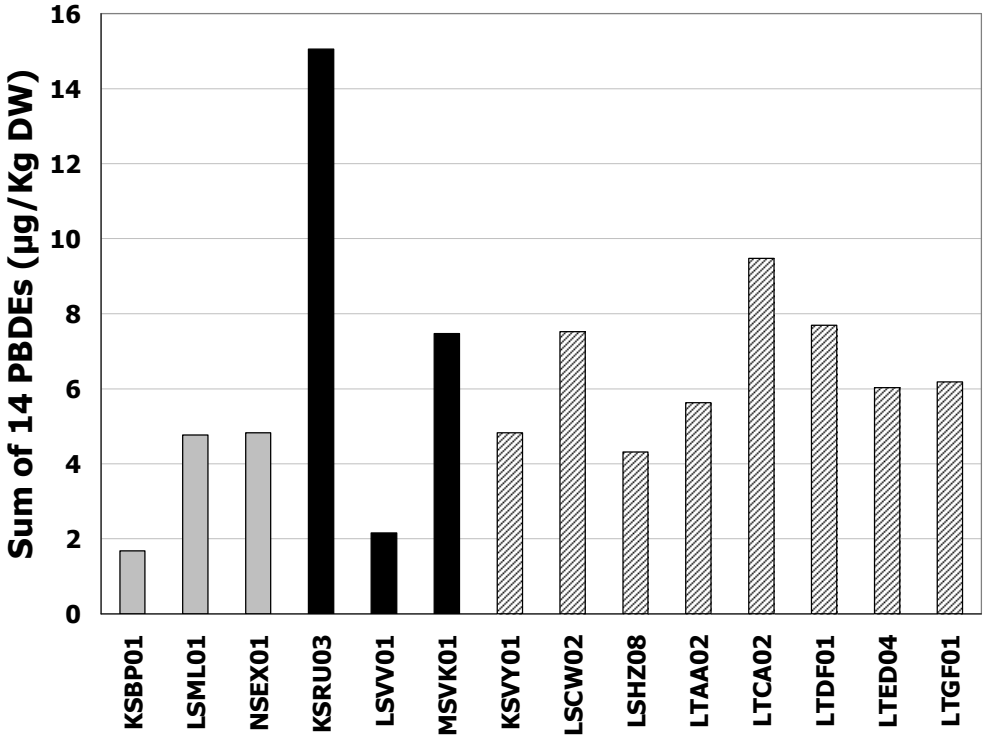


**Figure 4-10.** Sediment PBDE Concentrations at Central Basin (gray), Embayment (black), and Elliott Bay (hatched) Stations